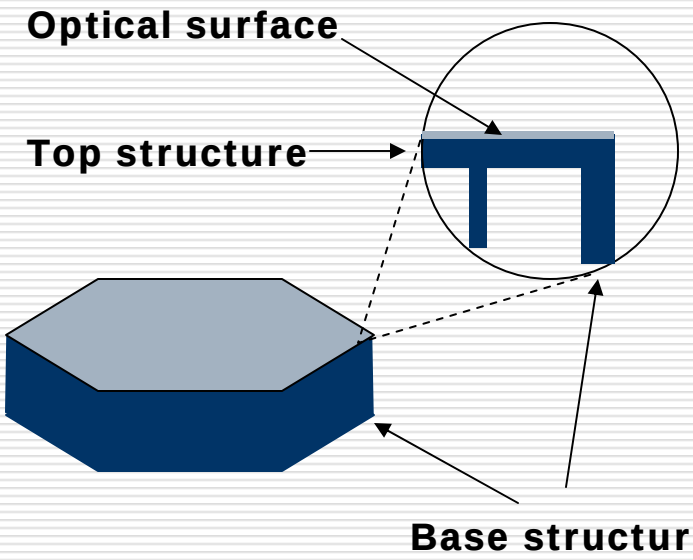
A Novel and New Ultra-Lightweight Reinforcement for Producing Low mass Optical Systems

Material & Electrochemical Research (MER) Corporation

SBIR Program Objectives

- Develop new material to reduce optical system mass
- Develop process to produce **isotropic** and hollow carbon fibers
- Use hollow fibers in composites to reduce weight by 25%-50%
- Use hollow fibers to produce composites for optical, optical structures and structural components
  - 8 cm sample mirror; 0.5 test mirror with 20 m radius
- Characterize composites made of hollow fiber isotropic carbon fiber to define structural and optical potential

Mirror Structure and Fabrication Progress



- 4” diameter (delivered)
  - Top structure: hollow isotropic CFs
  - Base structure: solid isotropic CFs
- 18” diameter (fabricating)
  - Top structure: hollow isotropic CFs (producing)
  - Base structure: solid isotropic CFs (produced)

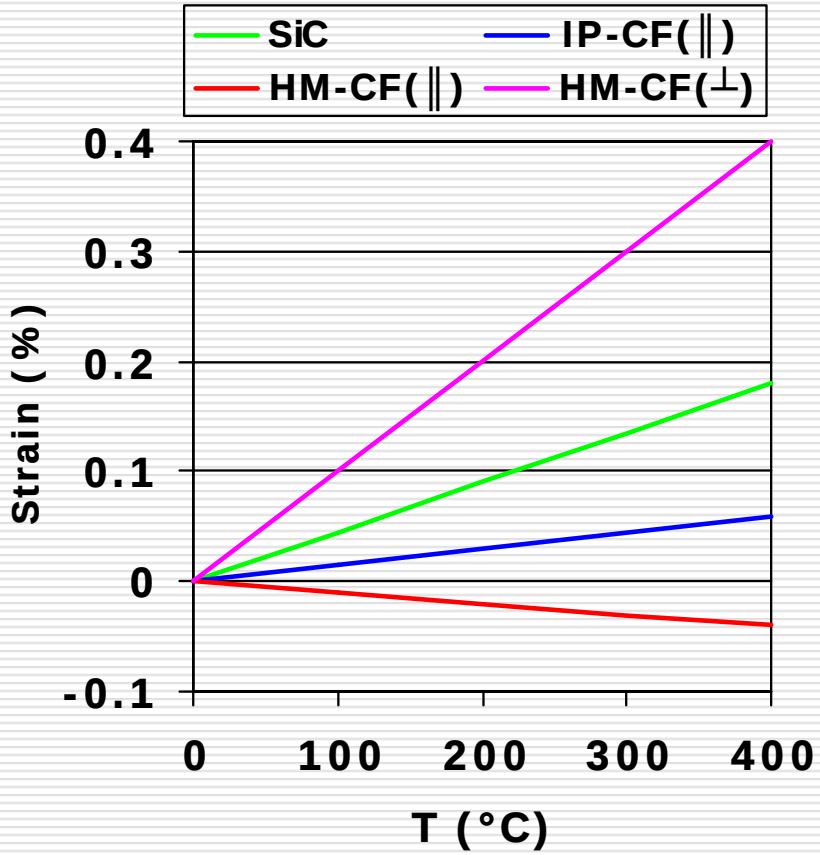
Properties of Candidate Materials*

	IP-CF	HM-CF	Si	GF	SiC-F	Al [b)]
Density (g/cc)	1.65~1.70	1.94~2.10	2.33	2.59	2.8	2.8
Modulus (GPa)	90~150	300~800	130~180 [a)]	80	180~350	70
Strength (GPa)	0.4~1.8	1.9~3.5	1.1 [a)]	2.8~3.5	2.8	0.2~0.5
Ultimate strain (%)	1.5~2.5	0.4~0.6	0.85	1.0~2.8	1.4	20
Conductivity (w/m-K)	2~10	50~1100	147	1.0	100~200	214
CTE ($x10^{-6}/K$)	0.9~1.7	-0.5~-1.5, ∥ 10, ⊥	2.8~7.3	2.8~9.0	4.5	15~22

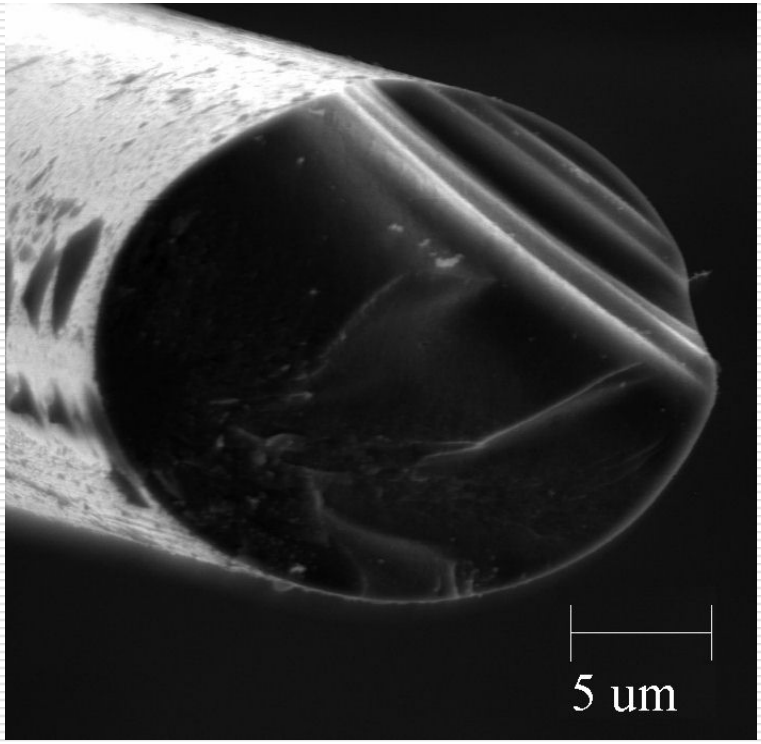
* Mostly for room temperature, and axial direction for fiber materials
a) Crystal silicon, b) including Al alloys.

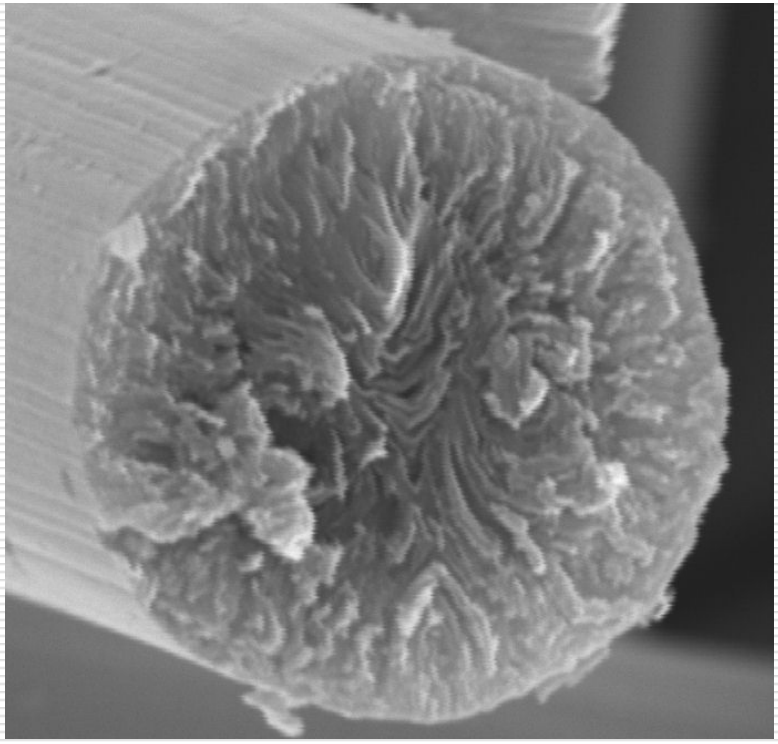
Simplified Model:
Dimension changes caused by high temperature

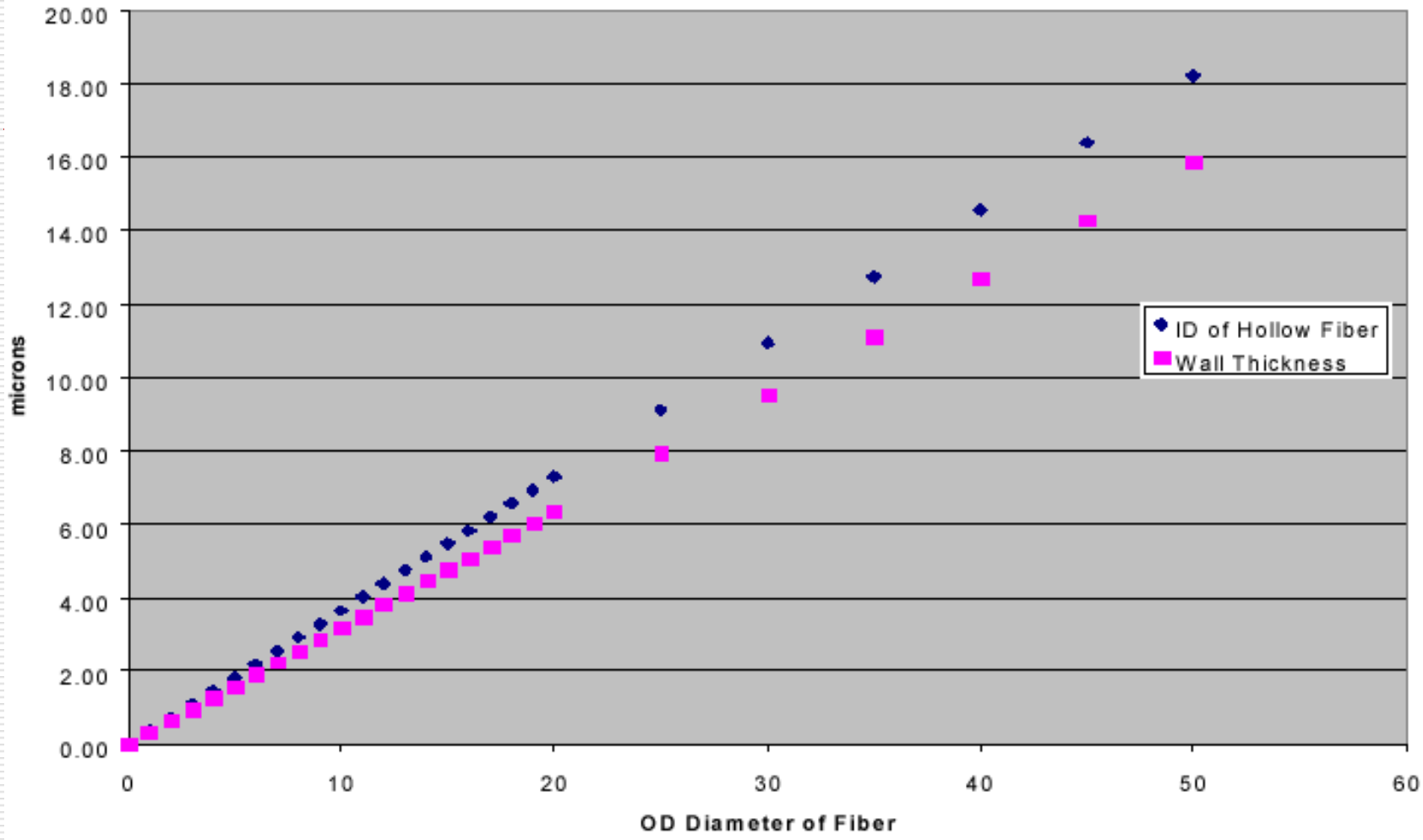
Materials	CTE (average, 10^{-6}/K)
SiC	3.0
IP-CF	1.5
HM-CF	-1.0 (∥) 10 (⊥)



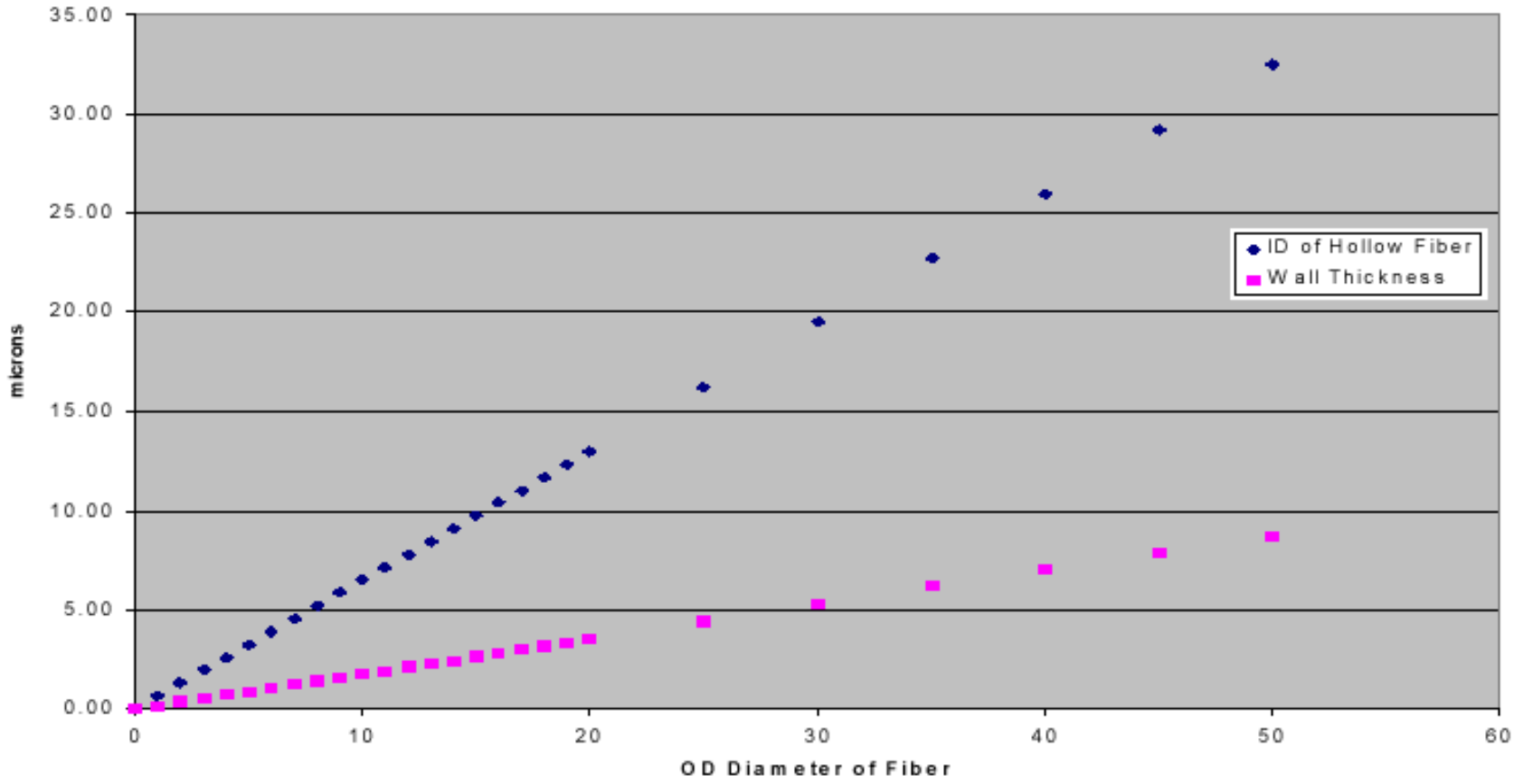
Difference in Structure between Pitch-based Isotropic and Mesophase Carbon Fibers





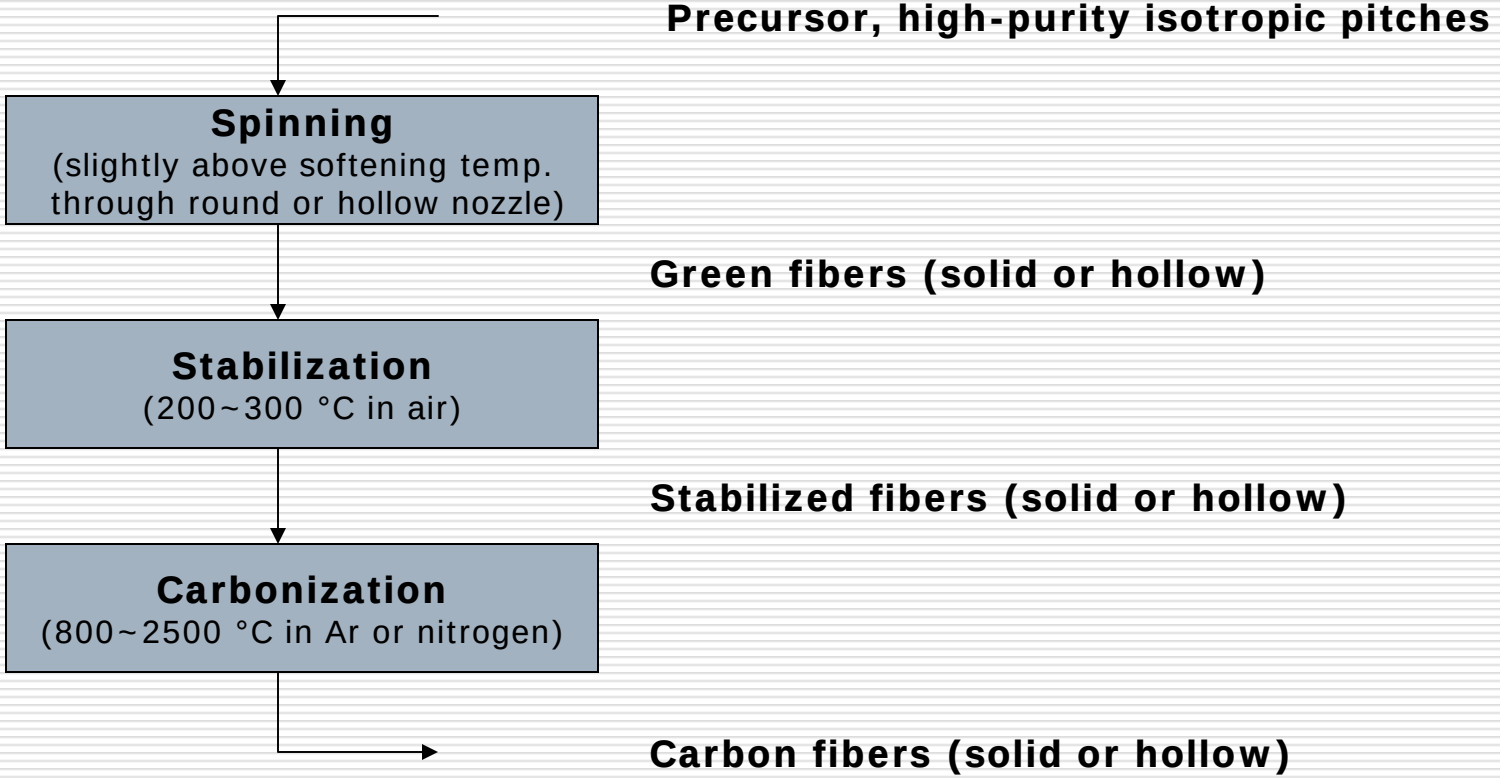


25% wt % savings over similar diameter C fiber



50 wt % savings diameter C fiber.

Process for Producing Isotropic Carbon Fibers



Scaling up Carbon Fibers Production

- Fiber spinning: from a few g/h to ~1 lb/h
- Stabilization capacity: gram to lb quantity
- Carbonization: ~ 1 lb upto 2500 °C
- Designed and debugged equipments and operating proce **isotropic** dures
- Developed methods and tools for specific forms of fiber products, in large quantity
  - Prepreg grade thin-layer products
  - Multi-filament yarn

Carbon Fibers Produced from Different Precursors, Using Multi-nozzle Spinneret

Carbon fibers made from:

- **Isotropic pitches**
  - Coal tar pitch
  - Petroleum pitch
- **Mesophase Pitches**
  - AR 500 (Mitsubishi)

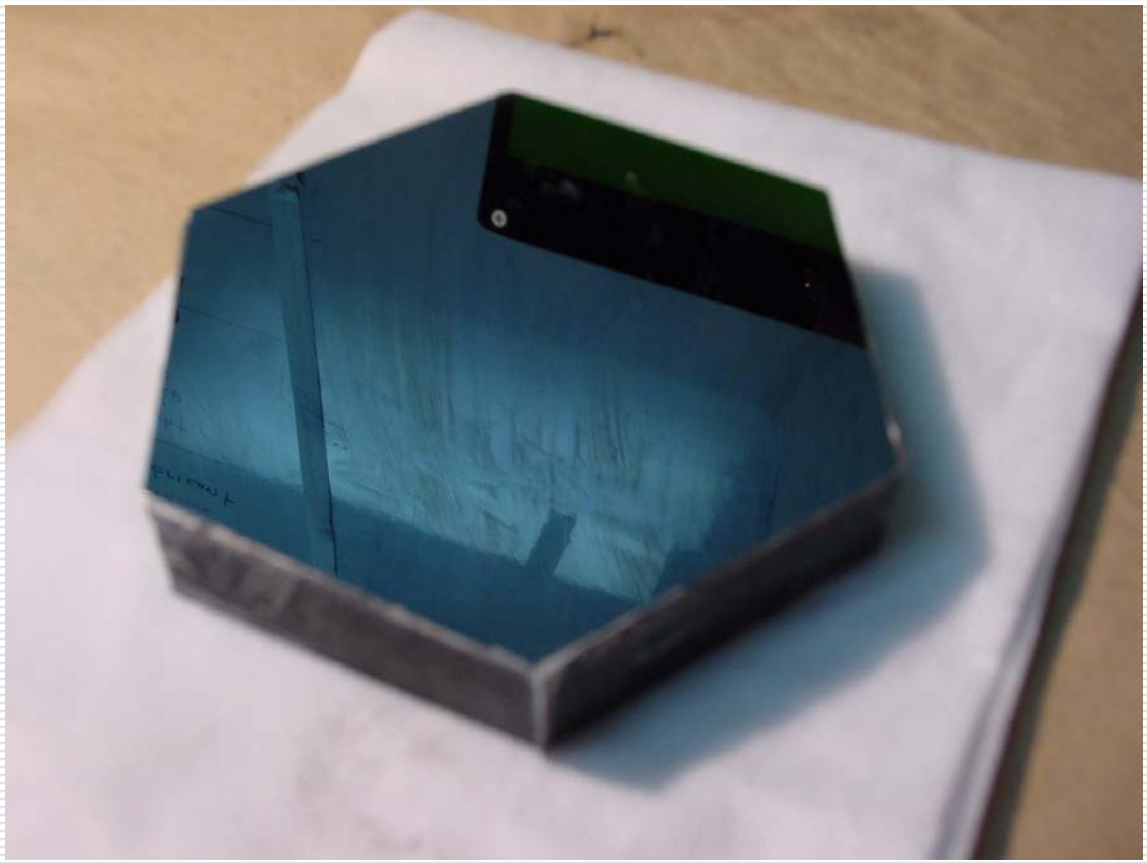
Pilot Scale Spinning Unit at MER

- Clockwise, Overview, precursor feeder and control panel

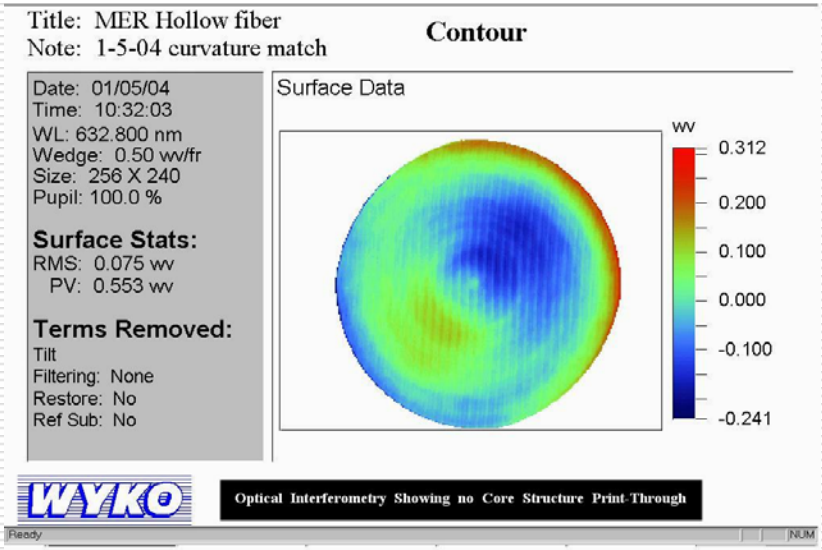
Carbon Fiber Products Made in Large Quantity:
– CF Thin Layer

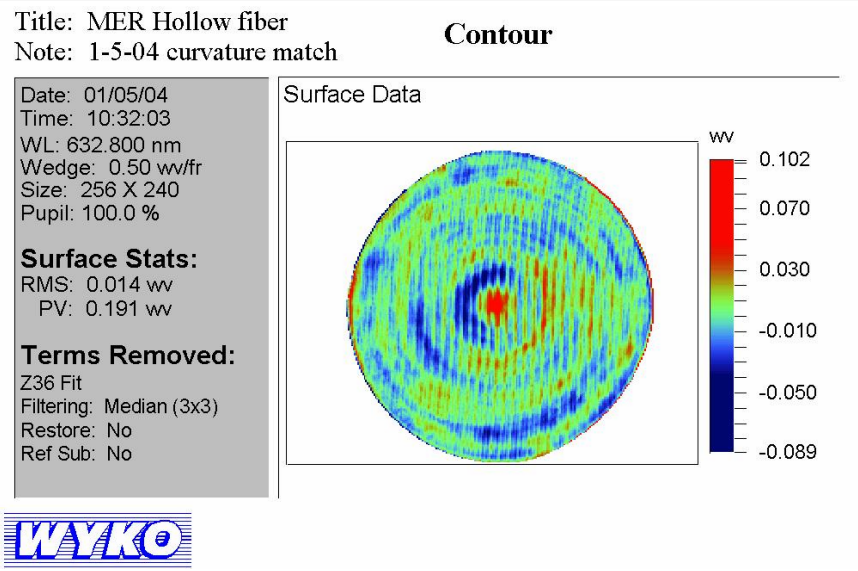
- **Thin-layered carbon fibers, ready for use as prepreg.**
- **18” long 12” wide carbonized isotropic fibers have been produced.**
- Issues of commercial isotropic pitch fibers (Ashland/Anshan or Kureha)
  - **No alignment**
  - **Discontinuous**

4“ Hollow Fiber Mirror



Surface Quality (4“ optic)





Micro-roughness (4” optic)

WYKO

Mag: 5.1 X
Mode: VSI

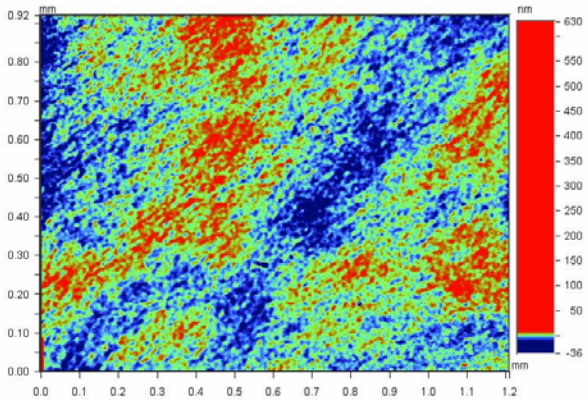
Surface Data

Date: 01/05/2(
Time: 11:26:4

Surface Statistics:
Ra: 4.07 nm
Rq: 11.10 nm
Rz: 390.97 nm
Rt: 665.26 nm

Set-up Parameters:
Size: 736 X 480
Sampling: 1.65 um

Processed Options:
Terms Removed:
Cylinder & Tilt
Filtering:
Median



Title: MER Hollow Fiber
Note: 5x 1/5/04

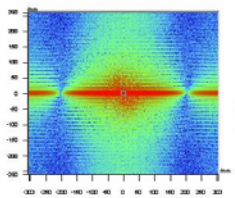
WYKO

Mag: 5.1 X
Mode: VSI

PSD

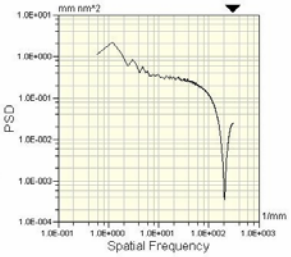
01/05/2004
11:26:48

PSD Plot



2D RMS: 3.53 nm
2D low cut off: 0.00 /mm
2D high cut off: 10.00 /mm

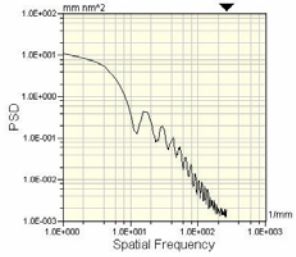
X Average PSD



X Average PSD Stats:

Low Cutoff: 0.000 /mm
High Cutoff: 0.000 /mm

Y Average PSD



Y Average PSD Stats:

Low Cutoff: 0.000 /mm
High Cutoff: 0.000 /mm

Title: MER Hollow Fiber
Note: 5x 1/5/04

What's Next

- Build 18" mirror
  - Solid isotropic fiber for honeycomb portion of mirror
- Produce hollow isotropic fiber for mirror surface
  - apply hollow carbon fiber to surface of honeycomb
- Apply interfacing layer to mirrors surface
  - grind
- Apply optical coating
  - polish
- Deliver mirror to MSFC